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COMPATIBILITY OF THE WAVE PERIOD PROCESSOR WITH THE TRESI CLASS--ETC(U)

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MOST Project -3

Technical Note on the Compatibility of the Wave Period Processor with the TRESI Classification System

24 September 1964

25 p.

Prepared by:
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Technical Note on the Compatibility of the Wave Period Processor with the TRESI Classification System

by G. S. Sebestyen

1. INTRODUCTION

On 18 September 1964, I was requested by Mr. Cornell Stradling of NEL to prepare a set of comments concerning the compatibility of the Wave Period Processor (WPP) with TRESI. I understand that comments on the same subject will be prepared by A. Gerlach of Cook Research Laboratories. Comments on this subject from Litton and from Cook have been invited by Commander Hahs (Code 1633, Bureau of Ships) and Mr. Lookingbill of NEL. I have prepared this technical note in compliance with the request. This technical note contains:

- A brief description of TRESI
- A brief description of the WPP
- A discussion of the compatibility of the WPP with TRESI
- A discussion of the compatibility of TRESI with sonar developments of the future
- Summary

1.1 BRIEF DESCRIPTION OF TRESI

TRESI recognizes the basic unreliability of even the best of classification clues and regards target classification as a problem in statistical decision-making. Decisions are rendered on simultaneously measured classification clues by a procedure which is designed to minimize the probability of incorrect classification. The equipment is composed of three functional blocks:

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- Operator console functions consisting of displays and operator controls.
- Signal digitization and clue extraction functions performed by a hybrid (analog-digital) data processor that measures, computes, and assembles the classification clues for processing by the clue evaluator.
- The clue evaluator which compares the measured clue patterns with each of a large number of computed clue patterns stored in its memory to determine the best match between input clue pattern and stored patterns, and to determine the probability that the present observations were caused by a submarine target. Additional interpretative displays are provided and several other functions (such as data collection and fire control input) are incorporated. For a more detailed description of TRESI, see the attached list of references.

As the sonar equipment undergoes changes and improvements, the nature of the classification clues used by TRESI is also expected to undergo changes. For this reason, the clue extractor data processor is programmable within the general constraints of the active sonar clue extraction problem to permit both the addition of new classification clues as well as the modification of clues used at present. The classification clues used in the present engineering model of TRESI are designed around the useful target attributes obtainable from the 30 millisecond and 2 millisecond pulse width modes of the AN/SQS-23 sonar. These clues, at present, include indications of:

- Target Doppler
- Pip Shape on the PPI or Range Bearing Indicator (part of TRESI)
- Pip Axis Angle as seen on a PPI or Range Bearing Indicator

- Leading Edge Alignment
- Trailing Edge Alignment
- Echo Length
- Number of Highlights
- Consistency of the Number of Highlights
- Echo Highlight Structure Consistency

Pip shape and pip axis angle are manually inserted by the operator; the remaining clues are automatically extracted. Of these classification clues, the first three are not particularly sensitive to variation in the transmitted pulse width; in fact doppler can be obtained more accurately with longer transmitted pulses. The Leading and Trailing Edge Alignments, while substantially more sensitive to transmitted pulse width, are nevertheless quite useable when the transmitted pulse width is increased to 120 or 200 milliseconds. Echo Length , the number of highlights, and the consistency of the number of highlights are expected to be influenced significantly by an increase in transmitted pulse width, since this would make it particularly difficult to distinguish beam aspect submarines from targets of other types. Since the range resolution capability of a 200 millisecond uncoded transmitted pulse is on the order of 500 feet, neither structural detail and highlight information nor an accurate assessment of the projected length of the target onto the bearing angle can be anticipated with long pulses. Consequently, the last classification clue, echo highlight structure consistency, (presently being added) would also have reduced significance for classification on uncoded long pulse transmissions. Of course, long duration pulse compression systems would yield the desirable highlight information.

The loss of range resolution capability suffered by the transmission of uncoded long pulses denies to any classification system (not only to TRESI) some of the classification clues from which the dimensions, the shape, the structure, and the structural consistency of the target can be determined and used as a basis for discriminating (among detected targets) between submarines and targets of non-submarine origin. Of course, there may be other classification clues which could be utilized with long pulse transmissions to aid target classification. If such exist, then TRESI in its present hardware form can use them along with present clues, because TRESI possesses the capability to automatically evaluate sets of clues, whatever may be their number and their type. It also possesses the capability of computing them automatically from automatically performed measurements on the sonar signal. The capability of the present TRESI hardware extends even to the computation of target maneuvering information obtained from internally measured range and bearing stored and processed over an extended period of time. In this respect, TRESI is a flexible automatic classification device which is not limited to the classification clues used at present and is not limited to the specific form of the AN/SQS-23 sonar as it exists today.

1.2 BRIEF DESCRIPTION OF THE WAVE PERIOD PROCESSOR

The WPP is capable of three modes of operation, one FM and two CW modes. A 200 millisecond CW waveform is transmitted during the two CW modes while a 200 millisecond duration FM slide is transmitted in the FM mode, covering a 400 cps deviation centered at 5 kc. After AGC amplification and zero crossing detection, the average period of the sonar return signal in each successive 8 cycles is measured, producing approximately

128 short term average wave period measurements in a 200 millisecond time interval. Target detection is based on the distribution of these wave period samples in a running window of approximately 200 milliseconds duration*. Various statistics of the distribution of 128 wave periods are obtained, the location of this window is advanced in steps of approximately 1.6 milliseconds, and the recomputed wave period statistics are used to intensify the range bearing detection display.

In the FM mode, it is said, in a noise or reverberation limited environment, the return due to a target is an FM slide, while due to reverberation, a more random distribution of zero crossing intervals is expected. The two CW modes are used to detect moving targets by virtue of the fact that average wave periods of moving targets are different from the average wave period due to reverberation or noise. Two quantities, one measuring the skewness and the other the amount not contained at zero doppler in the zero crossing distributions, are used to intensify the range bearing display.

As is seen from the very brief description above and from the somewhat more detailed one given in the Appendix, the WPP is designed to distinguish a reflector of acoustic energy from noise or from a distribution of reflectors represented by reverberation. The WPP was not designed to retain additional information about the contact that would permit classification by a more detailed analysis of the target structure,

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* A more detailed description of the WPP is given in the Appendix of this Technical Note, where an analysis and a comparison is also made between the operations performed by the WPP and similar operations performed by analog filtering techniques.

its consistency, etc. The inherent limitation of the WPP, from a classification point of view, is the lack of range resolution capability afforded by the transmitted waveform and processing technique. Strictly speaking, (referring to the FM mode) the WPP does not process the transmitted waveform optimally even from a detection point of view. With optimum processing techniques, a 200 millisecond duration, 400 cycle bandwidth FM waveform has a ~~2~~ 1 TW product of ~~160~~ 80 (or approximately ~~22~~ 19 db), which woud, if optimally utilized, provide a signal-to-noise ratio enhancement of ~~22~~ 19 db, and an ambiguous range-doppler resolution capability. This processing gain is not obtained by the WPP receiving system from the available transmitted waveform, although, as a significant compensating factor, the complexity and probable cost of the system is correspondingly lower.

1.3 COMPATIBILITY OF WPP WITH TRESI

TRESI uses video, audio envelope, and instantaneous audio frequency information from the sonar. The video information made available by the Wave Period Processor and used by it to present a range bearing display would be useable by TRESI without alteration. The difference between the PPI and the range bearing display is insignificant (in fact, TRESI uses a range bearing display on its own CRT display). The resulting display would be similar to the SUM display mode of the sonar except that the sizes of the blobs in bearing would be approximately half of those of the AN/SQS-23. This is not expected to influence classification performance significantly.

From the audio bearing angle TRESI obtains an instantaneous wave period measurement (in a manner almost identical to that used by WPP), and from the instantaneous wave period measurements the target doppler is computed within TRESI by averaging the wave period measurements over all highlighted intervals within a target isolation gate used to designate the target area. TRESI obtains the wave period measurements over an approximately 1.25 millisecond 1 cycle duration 800 cycle audio wave period, while the WPP obtains the wave period measurement over a 1.6 millisecond ~ 8 cycles interval of time from the 5 kc received audio. In the CW mode, the difference between these two wave period measurements is negligible. - not true SPP The wave period measurement from WPP could be used in place of the wave period internally measured by TRESI. In terms of the hardware, this would bypass a few logic cards in the TRESI equipment.

In the FM mode the "corrected" wave period measurement obtained internally in the WPP can be used as an indication of instantaneous frequency. This corrected wave period measurement is obtained in the WPP after the count in a 5 stage counter, simulating a saw-tooth FM waveform, is subtracted from the wave period measurement in the FM mode.

In brief, the so-called "binary count" listed on Page 11 of Reference 4 can be used as input to TRESI.

The highlight gating of the wave period measurements employed in obtaining a "target doppler" within TRESI can be obtained by using the short term statistic used in the WPP for intensifying the range bearing display.

The only other signals used in TRESI (besides sonar timing signals which remain substantially unaltered) is the audio envelope waveform. In place of the audio envelope waveform the running statistic used to intensify the range bearing display on the target bearing can be used as input to TRESI, bypassing a similar function performed within TRESI with only a few cards of equipment.

In conclusion, therefore, no technical difficulties would be encountered in mating the Wave Period Processor to TRESI to permit the two to function together. In this sense, therefore, the WPP and TRESI are compatible.

From the point of view of classification performance, however, the addition of the WPP to TRESI would significantly degrade the ability of TRESI (or of any other classification system) to classify targets. Three possible approaches can be considered for reducing the loss of classification capability due to the addition of WPP. The first approach requires no modification, whatsoever. It consists of transmitting shorter pulses (30 millisecond or 2 millisecond) for classification, and the 200 millisecond waveform of WPP for detection. These two modes of transmission could be interleaved or they could be switched by the operator. The advantage of this approach is that it requires no equipment modification on either the part of the WPP or on the part of TRESI. The disadvantage of this approach, however, is that the range at which classification of targets could be obtained is significantly reduced from the range at which they can be detected. If shorter pulse CW transmissions were unable to detect the target (and since they were not detected they could not be classified either), and if one had to go to WPP transmission and processing techniques to achieve detection, it follows that in those cases where the advantage of WPP over CW short pulse transmission is to be gained, WPP will detect targets while short

pulse transmissions will not. It is thus unavoidable that the result of using this approach of joint utilization of WPP and TRESI would result in a decrease of classification range compared to the detection range. Under the circumstances, this may be the only available solution.

A second approach to increasing classification performance (degraded originally due to the addition of WPP) is based on the development of an additional set of classification clues which may have merit even though the transmitted pulse length and processing technique denies the ability to obtain knowledge of target shape, structure, etc. While the above mentioned first approach (that of operating the sonar in one mode for detection and in a different mode for classification) would enable the maintenance of accurate classification capability on targets (at a reduced range), a simultaneous effort to develop additional classification clues (to replace those that became less useful) would, in time, result in regaining the classification capability at detection ranges, currently enjoyed by the match of TRESI and the AN/SQS-23. It is impossible to state at this time whether such classification clues exist and what performance could be achieved with them. This is also true for TRESI - 23. SPP

A third approach to increase the compatibility of WPP with TRESI consists of operating WPP with a shorter transmitted waveform (for instance 30 milliseconds). To determine the possibility of this approach, laboratory experiments are currently underway at the Information Sciences Laboratory of Litton Systems, Inc., to investigate the detection performance obtainable from processing techniques using wave period measurements as their basis on 30 millisecond pulse length transmissions. It is expected, of course, that a degradation in detection range (compared to longer transmissions) would be suffered but that a still significant improvement in detection range compared to CW short pulse transmissions would be obtained.

In these experiments, slightly different statistics of the wave period distribution are utilized. If promising results are obtained as a result of these experiments, a supplemental Technical Note will be submitted to document the detection range improvement (if any) achievable with short pulse CW transmissions. It is recognized, of course, that in earlier efforts during the design of WPP, shorter pulse transmissions were investigated. Similar investigations were conducted in this Laboratory about two years ago with 2 and 30 millisecond pulse transmissions. While detection was not the objective of the investigation at that time, improved detection ability was observed on short pulse transmissions using running statistics of instantaneous wave period measurements. It is not expected, as stated above, that detection range improvement comparable with that obtainable on longer pulse transmissions could be achieved.

1.4 COMPATIBILITY OF TRESI WITH SONAR DEVELOPMENTS OF THE FUTURE

While the Statistical Wave Period Processor has demonstrated improved performance in a reverberation-limited background over the standard SQS-23 sonar, the future trend in sonar development (going beyond the SQS-23 retrofit program) is toward large TW product pulse compression sonar systems of the type exemplified by the SQS-26, LORAD, La Spezia, and others. Significant future improvements in detection range of sonar systems will have to be based on an increase in the transmitted signal energy, which will have to be obtained through an increase in transmitted signal duration and/or peak power. Under given transducer and transmitter

peak power limitations, an increase in the transmitted signal energy can be achieved only through an increase in the transmitted pulse length and only if this is coupled with a receiver processor that coherently uses the increased pulse length. The WPP does not do so. To maintain the range resolution capability of the sonar system and to limit the ocean volume from which contributions to the return at a given instant of time are obtained, and in order that tracking and fire control needs should be met adequately, the maintenance of an adequate signal bandwidth (or equivalent pulse compressed pulse width) are required. A fortunate by-product of the transmission of long duration signals is the attendant increase in the doppler resolution capability of correlation type receivers. The ability to discriminate between targets and reverberation on the basis of doppler frequency is well known and also serves as the basis for the good performance demonstrated by the WPP. Since large TW product pulse compression systems employing correlation receivers combine the achievement of greater detection range through greater transmitted signal energy (without an increase in transmitter peak power) with the improved target-to-reverberation discrimination ability of the WPP (by virtue of the improved doppler resolution capability of pulse compression systems) and with the range resolution capability necessary to tracking, fire control and classification, it is my strong belief that the coming decade or more will see the evolution and general use of pulse compression sonars.

While the defense of pulse compression sonar systems is hardly the purpose of this Technical Note, the above brief enumeration of the advantages of such systems for future use and the forecast of their future take-over of the sonar field is necessary to set the stage for the discussion of the growth potential of the TRESI classification technique in its present form and also in a somewhat modified form recommended for future applications.

Sonar systems in the future will probably employ preformed beams, automatic target detection, and the display of targets or probable targets on a PPI or range bearing display. The ultimate desired objective of such a sonar system would be to present to the operator (or possibly to a machine) the range, bearing depth, speed, heading, and classification of each target within detection range together with a suitable display of the ocean volume in which detection can be expected under the prevailing conditions. From the point of view of target classification, the desired mode of operation of a future sonar system would require the ability to attach a classification tag to each blip displayed to the operator on his PPI or range bearing display. Since the number of blips appearing on such a display in the foreseeable future will be too numerous and the required classification computations to be performed per blip would be too complex to permit tagging each and every blip with a classification symbol, we must, for a very long time to come, accept the fact that a classification tag can be attached to only a subset of the blips appearing on the detection display.

Once we accept the fact that, because of the complexity of classification computations and the large quantity of blips on the detection display, automatic or semiautomatic classification tags can be assigned only to some of the blips on the detection displays, we have accepted a mode of operation in which targets or potential targets to be classified will have to be designated or "hooked" either automatically or manually. This implies that, on the basis of some priority assignment scheme, (determined and executed either by a computer, if one is part of the system, or by a human operator), selected targets are "hooked" and by this action the classification system is asked to supply classification symbols or tags to the selected targets. Thus, one might envision a system where, on the range bearing display, either a computer or the human operator "hooks" targets arousing suspicion and requests the classification system to supply classification tags and

reliability estimates on the "hooked" targets. This mode of operation is not unlike that already achieved in the radar field, and is in full agreement with the results of Navy studies such as those performed in connection with SSCDS and NTDS.

The role of a classification system in a sonar system of the type described above must be that of a rapid and reliable tool which is able to examine the characteristics of several designated targets simultaneously. The requirements for high speed, the simultaneous consideration of many target attributes and the rapid evaluation of the target attributes to provide the classification tags for the selected target has been demonstrated by the TRESI classification technique. The trend toward future classification systems is thus inevitably drifting toward the TRESI concept which can be summarized in the following: Is he pointing, leading, demanding, ... or just hoping?

- The target or targets to be classified are designated by the automatic or manual selection of the approximate target ranges and bearings.
- A set of potentially useful classification clues or measurements are made automatically to represent each target by a set of its attributes.
- The set of attributes representing the target or targets are evaluated and compared with stored information in a manner so as to result in the maximum probability of correct classification based on whatever information about target types of all sorts are available.
- The classification system must track the "hooked" targets sufficiently well to permit their continued classification analysis.

In order to enable the classification of targets, the maximum amount of information obtainable from any sonar system is limited to the amplitude, two-way delay, speed, and size of each phenomenon causing a sonar echo. Large TW product pulse compression sonar systems provide all of this information. The amplitude is measured by the instantaneous output of the correlator, the speed by the instantaneous doppler (which changes, in general, as often as the range resolution capability of the sonar permits it) and, we even get a measure of the instantaneous doppler distribution from which a reverberation-target discrimination decision could be made.

TRESI is definitely compatible with all pulse compression sonar systems anticipated by GSS in the future. TRESI, at present, uses two basic waveforms for all of its computations. One is the amplitude versus range waveform normally associated with the A-scan envelope; the other, the instantaneous doppler versus range which is computed internally in TRESI. In pulse compression systems, these two waveforms can also be obtained. Using the LORAD or SQS-26 type of pulse compression systems only as an example, the OR gated correlator output waveform has characteristics identical to those that would be obtained from the A-scan envelope during short pulse CW transmissions. By utilizing the "indicating OR gate" doppler filter identification output, an instantaneous doppler versus time waveform can be obtained with characteristics identical to that computed internally within TRESI from instantaneous wave period processing.

Thus TRESI could be applied directly to a pulse compression system like the SQS-26 by using the "indicating OR gate" output as the A-scan envelope waveform and by bypassing the internal instantaneous doppler computation circuitry of TRESI with the filter identity indicating portion of the correlator filter bank "indicating OR gate" output.

1.5 SUMMARY

From the foregoing description of TRESI, WPP, new sonar development trends, and the compatibility between WPP and TRESI, the following summary statements can be made:

- The WPP and the TRESI equipment can be mated readily with only minor modifications to the equipments. That is to say, no difficulties in interconnecting the two equipments are expected, and
- Using the transmitted waveform and receiver processing techniques of the WPP, many of the classification clues used by TRESI that describe target shape, size, and structural consistency become degraded with a resulting degradation of classification performance.
- Three approaches can be used to increase the compatibility of the WPP with TRESI:

  A. The first of these would use two transmitted waveforms (one for detection, another for classification). This would result in good classification capability but only on targets occurring at ranges less than the detection range.

  B. The second approach would concentrate on a development and addition of new classification clues obtainable from signals received from the WPP without necessitating hardware changes in either TRESI or the WPP. The prospects of developing such classification clues cannot be predicted at this time. Several months of development effort would be needed before a prediction could be made with any reasonable degree of certainty regarding its validity. In the interim time period, present classification clues and degraded classification range would have to be tolerated.

C. A third approach toward increasing the compatibility of WPP with TRESI would consist of using shorter transmitted pulse lengths in WPP; thereby suffering a degradation in detection range but still achieving an improvement over present detection ranges obtained with short pulse transmissions. This mode of operation is analagous to the approach outlined in (A) above.

- TRESI is definitely compatible with expected sonar developments of the pulse compression type. This compatibility is such that no hardware or mating difficulties are expected. No significant change in the classification clues used by TRESI are expected either. An orderly program of development of TRESI to mate both SQS-23 and expected sonar developments will be recommended at a later time.
- Pulse compression sonar techniques (even when the same transmitted waveforms are used) would demonstrate a better detection capability than WPP (at a greater cost and complexity). The use of such techniques would, in addition, preserve needed classification information. Considering its cost and availability, however, WPP is a good interim solution to the detection problem.

2. LIST OF REFERENCES

1. "A Synopsis of TRESI" by C. S. Stradling, an NEL internal memorandum, 30 April 1964, (CONFIDENTIAL).

This Synopsis, compiled from Litton progress reports on TRESI and from notes available in the TRESI files at NEL, is a concise, accurate document describing the TRESI equipment circa 1963. Significant differences between the equipment described in the SYNOPSIS and the present equipment exist; yet, this document is probably the best single, brief technical note on the system.

2. "TRESI, An Automatic Active Sonar Target Classification System" by G. S. Sebestyen, Journal of Underwater Acoustics, October 1964, (CONFIDENTIAL).

This is the single most concise written document of the TRESI concept, mode of operation, and a description of the equipment from a functional point of view. It does not contain a detailed description of the methods of computation or of the equipment design details.

3. "Phase II, First Interim Development Report for TRESI" by E. Ott, Litton Systems, Inc., 30 August 1962 (CONFIDENTIAL).

This report describes the functional design of the Clue Evaluator subsystem of TRESI.

Subsequent Phase II Interim Development Reports describing console and clue extractor functions are not accurate because significant changes in both console and clue extractor have been made since the reports were issued. Accurate descriptions of console and clue extractor functions are contained only in internal Litton working memoranda. The above listed reference 1, however, is sufficiently accurate for the technical support of this Technical Note.

4. "A Study and Development Program for a Sonar Signal Processing and Display System", Interim Report PR 176-13 covering the period 1 June 1962 through 31 August 1962, by A. Gerlach, Cook Research Laboratories (CONFIDENTIAL).

APPENDIX
THE WAVE PERIOD PROCESSOR

The Statistical Wave Period Processor is capable of three modes of operation, one FM and two CW modes. In order to determine the actual processing technique used by the WPP, a brief description of the system will be given in the following.

A 200 millisecond CW waveform is transmitted during the two CW modes, while a 400 cycle deviation 200 millisecond duration FM slide is transmitted in the FM mode.

In the CW mode, after AGC amplification and zero crossing detection of the (nominally) 5 kc carrier, the period of 8 consecutive carrier cycles is measured by counting 250 kc clock pulses. The average duration of an 8 cycle period is 1.6 milliseconds, and every approximately 1.6 milliseconds, a 5 bit number indicating the short term average wave period is obtained. In our further discussions this will be called the "period count". Period counts are obtained in non-overlapping windows of 8 carrier cycles each.

A running window of 128 counts (approximately 200 milliseconds in duration) is set up, and various statistics of the distribution of 128 period counts are obtained. Each is a running measure of certain echo characteristics from which target detection could be obtained. The location of the window is advanced, and the running statistics are recomputed approximately every 1.6 milliseconds. The resulting statistics are used to intensify the range bearing display.

In the FM mode, after AGC amplification, zero crossing detection, and wave period counting, the function of heterodyning by means of a swept FM or saw-tooth FM is simulated by adding to the wave period count the state of another 5 stage counter which simulates a saw-tooth waveform of opposite slope. If a target were present (in the absence of noise) the difference frequency between the target return (which is an FM slide) and the local oscillator (simulated by the saw-tooth counter) is a constant frequency, if the target two-way delay is some multiple of 200 milliseconds (the period of the saw-tooth). If the target range is different, two distinct frequencies will be obtained, the discontinuity in frequency occurring at the beginning of the saw-tooth period. The difference between the period count and the count of the saw-tooth FM counter is a modified or "corrected" period measurement. On this period measurement certain running statistics are computed over an approximately 200 millisecond time interval. The tabulation given below describes the statistics that are computed and presented to the CRT for display. A_i and B_i represent two different codings of all the corrected period count obtained from the i^{th} count in the window consisting of 128 counts. It is seen that A_i and B_i indicate up and down doppler measurements in the CW mode.

Mode	"Corrected" Period Count	Zone A Digit on i^{th} Period (A_i)	Zone B Digit on i^{th} Period (B_i)	Statistic Computed (s)	Useful in the Detection of
FM	0- 7	1	1	$S = \text{Max}\left\{ \left\| \sum_{i=1}^{128} A_i - 64 \right\| , \left\| \sum_{i=1}^{128} B_i - 64 \right\| \right\}$	Stationary targets in reverberation limited back-ground
	8-15	1	0		
	16-23	0	0		
	24-31	0	1		
CW-1	0-15	1	0	$S = \left\| \sum_{i=1}^{128} A_i - \sum_{i=1}^{128} B_i \right\|$	Moving targets in reverberation limited back-ground
	16-17	0	0		
	18-31	0	1		
CW-2	0-14	1	0	$S = \sum_{i=1}^{128} \left(A_i + B_i \right)$	
	15-18	0	0		
	19-30	0	1		

The following interpretation of the operations performed by the WPP in its three modes of operation is offered.

OPERATING MODE CW-2

The WPP function performed in the CW-2 operating mode is easily understood. It is somewhat analogous to introducing a sharp notch rejection filter at the carrier frequency, and following this by an envelope detector, the output of which is used to intensify the CRT. This is readily seen from the equation shown in the Table, where an output of "1" from the "zone A" output is an indication that the instantaneous wave period represents an up doppler signal, while an output of "1" from "zone B" indicates that the instantaneous doppler is down. Thus, the total count in the 200 millisecond long window indicates the number of up or down doppler wave periods, while the sum is merely proportional to the output that would be obtained if wave periods having "no doppler" were omitted. This is similar to the action of a notch filter centered at the carrier frequency. The performance of this device, however, is not as good as that which could be obtained from a notch filter because the echo wave period measurements themselves are very highly a function of the signal-to-noise ratio. A comparative analysis of the behavior of a notch filter with the CW-2 mode of WPP operation indicates improved performance for a notch filter.

OPERATING MODE CW-1

In this mode the WPP essentially measures the skewness of the wave period distribution in the 200 millisecond windows. A measure of this skewness is obtained, as seen from the equation, by measuring

the difference in the number of wave periods lying above versus those lying below zero doppler. The zero doppler itself is eliminated by the simulation of a notch filter.

FM OPERATING MODE

The central idea underlying the FM mode of operation of the WPP is that a target should produce an FM slide as its echo, or (after heterodyning with the saw-tooth reference) a target should produce a constant frequency output. A target will produce two different frequencies if the recycle time of the saw-tooth falls within the target echo interval. The corrected period counts due to a target, therefore, should be contained in substantially only a single bin. The WPP counts the number of wave periods that fall in close proximity of one another and makes some adjustments to account for those cases where the target return is split by the recycle time of the reference saw-tooth.

Since reverberation is usually a distributed target (can be regarded as many targets at different ranges), the return from reverberation will be smeared in frequency at every instant of time. The period count distribution will also occupy a large range of counts.

In either mode of operation the basic range resolution capability (highlight information) available from the WPP is that corresponding to 200 millisecond pulse transmissions. Thus only limited highlight information can be obtained from the WPP for classification purposes. This fact would influence the compatibility of the Wave Period Processor with TRESI (using the present clues), ASPECT, or any other system of sonar classification that attempts to make use of target highlight information.